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Tornga, Blake, J., LCDR USN

Paper Advisor (if Any): McPherson, Scott, J., CDR USN

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Military forces are utterly reliant and irretrievably wed to the electromagnetic spectrum. Unfettered use of the electromagnetic spectrum is a critical requirement in generating and applying combat power in 21st century across all of the warfighting functions. U.S. military operations within the electromagnetic spectrum—and the resultant benefit and strength for American forces—are in jeopardy. As our demands on the spectrum expand and our enemies' abilities to utilize the spectrum increase, our ability to continue to coordinate activities within the spectrum is growing more and more problematic. Past programs of frequency deconfliction as the primary means for coordination are insufficient in an environment that requires maximum efficiency in the use of the spectrum. Additionally, civilian thirst for spectrum usage has led to portions previously reserved solely for military operations being auctioned to commercial enterprise. Furthermore, Electronic Warfare (EW) efforts regarding the spectrum are generally uncoordinated either at the tactical or the operational level, and have consequential second and third order effects. Finally, long inattention to EW and frequency management competencies has left forces vulnerable within the electromagnetic battlespace.

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U.S. Military Operations Within the Electromagnetic Spectrum: A Critical Weakness

by

Blake Tornga

LCDR, USN

A paper submitted to the Faculty of the Naval War College in partial satisfaction of the requirements of the Department of Joint Military Operations.

The contents of this paper reflect my own personal views and are not necessarily endorsed by the Naval War College or the Department of the Navy.

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Abstract

Military forces are utterly reliant and irretrievably wed to the electromagnetic spectrum. Unfettered use of the electromagnetic spectrum is a critical requirement in generating and applying combat power in 21st century across all of the warfighting functions. U.S. military operations within the electromagnetic spectrum—and the resultant benefit and strength for American forces—are in jeopardy. As our demands on the spectrum expand and our enemies' abilities to utilize the spectrum increase, our ability to continue to coordinate activities within the spectrum is growing more and more problematic. Past programs of frequency deconfliction as the primary means for coordination are insufficient in an environment that requires maximum efficiency in the use of the spectrum. Additionally, civilian thirst for spectrum usage has led to portions previously reserved solely for military operations being auctioned to commercial enterprise. Furthermore, Electronic Warfare (EW) efforts regarding the spectrum are generally uncoordinated either at the tactical or the operational level, and have consequential second and third order effects. Finally, long inattention to EW and frequency management competencies has left forces vulnerable within the electromagnetic battlespace.

INTRODUCTION

U.S. military operations within the electromagnetic spectrum—and the resultant benefit and strength for American forces—are in jeopardy. As our demands on the spectrum expand and our enemies' abilities to utilize the spectrum increase, our ability to continue to coordinate activities within the spectrum is growing more and more problematic. Past programs of frequency deconfliction as the primary means for coordination are insufficient in an environment that requires maximum efficiency in the use of the spectrum. Additionally, civilian thirst for spectrum usage has led to portions previously reserved solely for military operations being auctioned to commercial enterprise. Furthermore, Electronic Warfare (EW) efforts regarding the spectrum are generally uncoordinated either at the tactical or the operational level, and have consequential second and third order effects. Finally, long inattention to EW and frequency management competencies has left forces vulnerable within the electromagnetic battlespace.

Military forces are utterly reliant and irretrievably wed to the electromagnetic spectrum, irrelevant of the nature of the battlefield. Whether operating on the land, air, or sea, and independent of the type of forces (be it modern equipped conventional forces or 3rd world irregular warriors) unfettered use of the electromagnetic spectrum is a critical requirement in generating and applying combat power in 21st century across all of the warfighting functions.

For example, precision of lethal *fires* utilizing radar, GPS, and Link-16 takes advantage of the principal of economy of force within the framework of limited objective warfare. *Command and control* of mobile forces is accomplished through communications systems utilizing the electromagnetic spectrum such as satellite telephones, push to talk

radios, cell phones, blue force tracker, and wireless computer networks. Electronic Warfare is leveraged to deny the enemy the use of the spectrum in an attempt to place him in a position of disadvantage, thereby utilizing the principle of *maneuver*.[1]

Furthermore, the DoD is developing the Global Information Grid (GIG) as the heart of its future Network-Centric Operations to link sensors, intelligence, shooters, and command and control. "It [the spectrum] is the essential resource that enables the operation of wireless networks and vital components on virtually every tactical warfighting system."[2] As debate continues over the extent to which Network-Centric Operations (NCO) transforms the nature of warfare, the U.S. Department of Defense (DoD) continues its "force transformation" from the industrial age of to the information age. While NCO may not be the revolution in military affairs clained in the 1990s, military conflict over the last decade has clearly shown its utility[3] and it remains central in the DoDs strategy to maintain a decisive warfighting advantage. As General David Petraeus, Commanding General, Multi-National Force - Iraq, has asserted, "[i]t's [network-centric warfare] definitely her to stay. It's just going to keep getting greater and greater and greater."[4]

THE SPECTRUM

One need not have a complex understanding of how electronic gadgetry functions to manipulate electromagnetic waves into military effects in order to understand the shortcoming of the current spectrum management structure. However, a short explanation of the electromagnetic spectrum and a brief historical examination of its use are necessary and helpful for the purpose of this study.

We physically pass information wirelessly through space by transmitting encoded electromagnetic waves at a particular frequency. These waves possess different characteristics depending on the frequency transmitted. Some frequencies are able to travel extremely long ranges, but require large bulky hardware to utilize them. Other frequencies can be processed by lightweight, compact hardware, but are quickly absorbed by the environment, making them useful over relatively short distances. The electromagnetic spectrum is a construct used to group frequencies with similar characteristics together in order to avoid interference. While the electromagnetic spectrum ranges in frequency from 3,000 to 300,000,000,000, only around one percent of the spectrum is suited for contemporary systems and yet accounts for ninety percent of the use of the spectrum. This most desirable portion of the spectrum lies below 3,100,000,000 Hz or 3.1 GHz.[5]

Ideally, any receiver designed and tuned to the frequency of the transmitted wave can intercept it and reject all other waves as unwanted noise. However, transmitted waves cannot be generated at a singe frequency, and likewise receivers cannot intercept and process a single frequency. When a system is said to be operating at an individual frequency, in actuality the bulk of power is centered at that assigned frequency, while simultaneously other waves are being transmitted at near frequencies. Accordingly, "many receivers will be unable to reject the unwanted signals as noise without the use of expensive filters and digital processing devices, and even with these devices, many receivers will be unable to eliminate unwanted signals entirely. Instead, users will experience the unwanted signals as interference, which either interrupts or disrupts the desired service. Thus, radio signals transmitted on the same or adjacent frequencies, within the same general area, and at the same time tend to interfere with on another."[6] Simply put, devices that operate using the

same frequency or frequencies very close to each other, or that don't comply with regulatory technical design will render each other unusable. The consequences on the battlefield could be precision guided munitions that are unable to receive GPS signals due to interference, or two ground units unable to communicate and coordinate fires.

THE TRADITIONAL FREQUENCY MANAGEMENT CONSTRUCT

The system that we use to avoid this interference relies predominately on allocating or licensing the use of a particular frequency, restraining the geographic area of transmission, and limiting the power transmitted. The foundation for this construct was first created in the U.S. by the 1912 Act to Regulate Radio Communication in response to possible radio interference during the Titanic rescue attempt. During this time, uses of electromagnetic waves were predominantly point-to-point wireless radios, used primarily for maritime communication. Little interference was encountered at the time due to the small number of users of the spectrum and the great physical separation of users involved in the maritime domain.[7]

Electromagnetic interference (EMI) was becoming a massive problem by the early 1920s as U.S. domestic radio broadcast competed for audiences. Without regulation, stations within the same geographic area increased power in an attempt to reach greater distances and larger audiences. Increased power of the center broadcast frequency had the side effect of higher power on the unintended transmission of the frequency near the center frequency, interfering with competing stations. "By 1927 more than 700 broadcast stations were operating fairly chaotically, changing frequencies and increasing power at will."[8] In response, the Communications Act of 1934 provided for a governing body and the Federal

Communication Commission (FCC) was created to "license radio stations, prevent chaos, and ensure public safety."[9]

The FCC drew on the 1912 construct of deconfliction by frequency, geography, and power by creating the grouping of frequencies with similar characteristics and uses that we now consider to be the electromagnetic spectrum. Accordingly, technical rules governing the hardware specifications required within each block of frequencies was established to reduce the effects of interference; and licenses were issued giving the holder exclusive right to the use of a particular frequency for a particular purpose. Generally speaking, this is the same construct still used by DoD to allocate the spectrum.[10]

For the last century this construct of frequency allocation has been fairly effective at eliminating interference between users. However, its inefficiency is quickly becoming evident. For example, military aviation squadrons are often assigned individual frequencies for tactical voice communications between aircraft. This very necessary safety of flight communications requires complete, uninterrupted use of that portion of the spectrum during all portions of flight. During the time that flight operations are not being conducted, this assigned portion of the spectrum is still assigned for this specific purpose and is unusable to all other possible users.

NOT ENOUGH ROOM

As noted, there has generally been enough room in the spectrum for most users to have access, despite inefficiency. However, recent demand on the spectrum has exploded and users still maintain the expectation of unfettered reliability. Meanwhile, the supply of spectrum remains and will always remain constant and finite. While the spectrum itself is

indestructible, we cannot produce, mine, grow, or purchase additional spectrum, and thus we can run out of its capacity to support all of our uses. As the NTIA points out:

> Until recently, emerging technology could utilize unallocated portions of the spectrum. As demand for spectrum has increased, technology has developed radios that can perform the same function at higher unused frequencies or increase spectrum efficiency and re-use of existing frequencies. Now, demand for spectrum is growing rapidly, both from expanded use of current services like cellular radio and precision landing systems for improved aviation safety, and the development of uses, such as PCS, digital audio broadcasting, advanced television, and satellite sound broadcasting. However, the technical advances needed to meet that demand may be 'pushing the envelop' of practicality, at least in the short term. New technology cannot be expected to achieve further spectrum efficiency in the crowded radio spectrum below 3 GHz.[11]

The military is far from alone in its expanding need of spectrum resources. Pressure from commercial users for more access to more frequencies and ranges has resulted in the auction of portions of the spectrum formerly held for exclusive use by DoD. Some of the spectrum sold "had been allocated to DoD in the UHF portion of the spectrum and was a serious loss to military operations, in terms of both capability and cost to relocate military users to new frequencies."[12] While these auctions impinge on the military, the positive impact on the economy through the introduction of new commercial services and products ensures that their will be continued pressure for more. Currently, of the most used portion of the spectrum (that under 30,000 MHz) non-government exclusive allocation is 30%, the federal government exclusive allocation is 7%, and the remainder 63% is shared.[13]

The competition for use of the spectrum between private, public, and federal government agencies is exasperated by the lack of a national strategic focus and lack of a unified structure. The Federal Communication Commission (FCC) regulates private and public interests within the spectrum and reports to Congress while the National Telecommunications and Information Administration (NTIA) regulates federal use of the

spectrum and reports to the President through the Department of Commerce. Synchronization between these organizations is only informally coordinated. Within the NTIA, the Interdepartment Radio Advisory Committee (IRAC) coordinates the federal government use. Of the 22 representatives on the IRAC, DoD occupies a mere three seats.[14] The relatively weak influence of the DoD on the spectrum allocation process puts it on a permanent reactionary defense against encroachment on needed spectrum.

Recognizing the lack of a national-level coordinated strategy with regards to the spectrum, the President directed the NTIA, with consultation of the FCC, to create a National Strategic Spectrum Plan in 2003. The plan, which was published in March of 2008, addresses expanding federal government spectrum requirements and recognizes the shortfalls of current frequency management abilities. However, it still falls short of coordinating FCC and NTIA efforts, leaving the division between the two unresolved. "With respect to future non-Federal spectrum requirements, such needs generally are driven by market forces as well as state and local public safety requirements, which are difficult to project over the long run. Moreover, pending collaboration with the FCC on development of a National Strategic Spectrum Plan, information concerning future non-Federal agency spectrum requirements can only be inferred by the rapid growth of new wireless technologies and services over the past few years."[15] Comparison of the new National Strategic Spectrum Plan and the FCC Strategic Plan 2006-2011[16] reveals an acknowledgement of needed cooperation, but the plans do little in achieving a common focus. The FCC plan in fact bolsters the competition between federal and public/private concerns as beneficial. "Jurisdictional issues between the agencies charged with spectrum management (in particular NTIA and FCC) and competing demands might lead to new ways to achieve more efficient spectrum management."[17]

THE SPECTRUM AND NETWORK-CENTRIC OPERATIONS

Despite the current technological restrictions of operating in underutilized portions of the spectrum above 3GHz and the already crowded use of the spectrum below 3GHz, expanded use of the spectrum is at the very heart of the military's transformation to a network-centric force. The Federal Strategic Spectrum Plan published in March of 2008 outlines anticipated spectrum needs to fulfill a "future shaped by 'Network-Centric Warfare'."[18] "DOD anticipates significant additional requirements through 2015 and beyond, regardless of modernization efforts, with the biggest growth in the frequency bands below 3GHz."[19]

The achievement of these goals is not possible without a drastic increase in efficiency in the use of the spectrum, a reality that the DoD readily acknowledges. As noted by the U.S. Department of Commerce, "DOD recognizes that future spectrum requirements growth may not be fully supportable without advances in spectrum-utilization technologies and changes in spectrum management concepts and approaches."[20]

These "spectrum-utilization technologies" include software-defined radios that can be reprogrammed to function across vast portions of the spectrum. Software-defined radios can gain efficiency by integrating "dynamic spectrum management". These so-called "smart radios" (such as the new Joint Tactical Radio System (JTRS)) can automatically determine efficient use of the available spectrum. Additionally, spread spectrum communications allows multiple signals to use the same frequency spectrum simultaneously for multiple purposes.[21]

Some technologies required to fulfill the strategy are proven concepts while some are

still considered emerging technologies. They either rely on technical standards and protocols to eliminate interference within a "spectrum commons", or self-regulating technology within the device, which selects useable portions of the spectrum with an "exclusive use" construct.[22] These systems will require substantial investment in development, but further, they may require a change in the way we view and administer the spectrum.

Nevertheless, these technologies do not fit the traditional model of deconfliction by frequency allocation, geography, and power, but rather cooperatively function outside the bounds of a single frequency assignment. This has led to debate as to the usefulness of the current administrative frequency deconfliction structure. According to a 2004 General Accounting Office Report, "Currently the spectrum allocation system may not provide the freedom needed for these technologies to operate across existing spectrum designations."[23]

Some experts advocate for elimination of the current allocation system in lieu of a "spectrum commons" that would allow the devices to self-regulate the spectrum to avoid interference, thereby greatly increasing efficiency.[24] However, potential domestic and international regulatory and legal issues plague the leap to such a construct. Additionally, neither the NTIA nor the FCC has sufficient models to predict interference under a "spectrum commons". Near term change to the legacy spectrum management construct is very unlikely.

ENTER ELECTRONIC WARFARE

While there are profound consequences for military operations that require spectrum that may be unavailable for its use, our ability to control the enemy's use of the same spectrum also influences military outcomes. The abundance of inexpensive commercial technologies has given even unsophisticated enemies access to a robust command and control

structure using off-the-shelf cell phones, long-range cordless telephones, hand held radios, satellite phones, and wireless wide area computer networks. Additionally, foreign nations are rushing to incorporate electronic warfare into military capabilities.[25]

Our attempts to counter enemy use of the spectrum are known as Electronic Warfare (EW) and consist of three subdivisions. Electronic Attack (EA) is our attempt at denying the enemy ability to operate within the spectrum. Electronic Warfare Support (ES) is our attempt to exploit our enemy's use of the spectrum by collecting signals. Electronic Protect (EP) is our attempts to protect friendly forces from the enemy's use of the spectrum.[26] These activities should be closely coordinated in order to achieve the sought after effects on the enemy while preserving the friendly use of the spectrum. However, coordination between the components of EW has happened infrequently and only on an ad hoc basis at either the tactical or operational level of warfare. Legacy tools traditionally used to coordinate these efforts are proving inadequate in the dynamic and congested spectrum battlefield of the 21st century. Additionally, at a time when the military is in growing need of expertise in electromagnetic spectrum management and electronic warfare, it finds itself divested from these skills.

Traditionally each subdivision of electronic warfare has been conducted independent of each other due to differing objectives and service specific capabilities. For example, EA was conducted by the Navy EA-6B *Prowler* aircraft primarily to jam radar and communications for the suppression of enemy air defense (SEAD). EA was also conducted separately by the Air Force EC-130 primarily to jam battlefield communications. Simultaneously but independent of these operations, ES was conducted by the Air Force RJ-135 to provide intelligence, surveillance, and reconnaissance (ISR) to command

headquarters. Independent of the Air Force effort, national ES assets were used by various organizations to conduct separate ISR missions. Separate from any of these activities the EC-130E Commando Solo conducted psychological operations broadcasts. Rarely were any of these efforts coordinated to deconflict the use of the spectrum, and often the activities of the ES assets were interrupted by activities from EA assets. Additionally, ES collection information that might be useful for refining EA targeting was rarely relayed to EA platforms. An anecdote from Operation Desert Storm illustrates the problem with the lack of coordinated operations: "[o]n one occasion I was on orbit conducting jamming operations, and we knew an EC-130E Commando Solo aircraft was in the are putting out [psychological operations] broadcasts to Iraqi troops. But we didn't know the frequencies or the times when it was operating. A linguist misidentified a broadcast, we targeted it and we ended up jamming it. We discovered the mistake only after we landed."[27]

The primary tool used to coordinate friendly use of the spectrum with ES and EA is the Joint Restricted Frequency List (JRFL). Frequencies that are deemed "necessary for friendly forces to accomplish objectives"[28] are listed and classified as guarded, protected, or taboo. Guarded frequencies are potentially being exploited by friendly forces for intelligence, protected frequencies are in use by friendly forces for operations, and taboo frequencies are high importance friendly frequencies that are never to be jammed. The JRFL is arranged under a similar construct as spectrum management in that the primary means of separating users of the spectrum is by frequency. Recently, as both friendly and enemy use and reliance on the spectrum has increased, the JRFL is no longer sufficient to deconflict the spectrum.

In the past, the JRFL had appeared to work fairly well at deconflicting electronic warfare effects with friendly use of the spectrum. Jamming, often considered primarily a suppression of enemy air defense (SEAD) weapon, was operated for a fairly limited amount of time, directed "down range" past the Forward Line Of Troops (FLOT), affecting mostly enemy devices. Friendly jamming interference was considered a cost of doing business and operators selected another portion of the spectrum or were forced to find "work-arounds" when systems were momentarily disrupted due to electronic fratricide. When "work-arounds" weren't sufficient, and portions of the spectrum were placed on the JRFL as taboo frequencies, jamming assignments were re-written to avoid those portions of the spectrum, at the same time diminishing the effectiveness of the jamming.

As the number of uses and users of the spectrum on the battlefield has increased there are no longer "other portions of the spectrum" to select when interference is encountered. As our reliance on the spectrum increases all frequencies are becoming critical and worthy of protected or taboo status.

The JRFL as the primary coordinating tool is poorly suited for prioritizing friendly use of the spectrum for communication, jamming of the spectrum for protection, or for surveillance of the spectrum for intelligence. The inefficiency of the JRFL is comparable to the inefficiency of the sole use frequency assignment construct used at the national frequency management level. The dynamic nature of the enemy use of the spectrum isn't supportable by the fairly static nature of the JRFL. Paige Atkins, director of the newly formed Defense Spectrum Organization succinctly explains: "[r]ight now, our spectrum information – the databases, the information systems and the modeling and simulation capabilities – aren't really adequate for the complex, dynamic and congested environments that we're starting to

face now and that we will face in the future, so that inhibits our ability to adequately plan and execute operations."[29]

Meanwhile, the enemy in Afghanistan and Iraq are using simple radio technologies such as cell phones, wireless doorbells, wireless garage door openers, and hand held radios as triggering devices for Radio Controlled Improvised Explosive Devices (RCIEDs). General William Nyland, Assistant Commandant of the U.S. Marine Corps testified to the House Armed Service Committee on 21 June 2005 that, "Cellular, Satellite, Long Range Cordless Telephone and FRS Radio Jammer [*sic*] have become the worldwide number one initiator of IEDs."[30] To counter this threat, the U.S. quickly fielded a myriad of jammers that worked fairly well at disrupting RCIED triggers by jamming the frequency ranges of cell phones, hand held radios, and satellite radios. However, friendly forces rely on the same frequency ranges, causing interference for units trying to communicate using this portion of the spectrum, intelligence operators attempting to collect within this portion of the spectrum, and unmanned aerial vehicles being controlled using this portion of the spectrum. As Lieutenant General Walter Buchanan, commander 9th Air Force and U.S. Central command Air Forces pointed out in a 2005 statement, "This is the first time we have seen electronic fratricide reach the point it has."[31]

Further exasperating the problem, the immediacy of the problem allowed the jammers to be fielded without normal interoperability testing and without the normal "Application for Equipment Frequency Allocation". No one knew the specific impacts that the jammers would have within the spectrum or how to deconflict from friendly spectrum use utilizing the JRFL as the primary tool. Without the proper deconfliction tools, the military sought out personnel with experience in spectrum management and electronic warfare to

reduce the interference. However, there were only small numbers of electromagnetic expertise held within small pockets of each service. After the cold war, the Army had eliminated its Combat Electronic Warfare and Intelligence Operations and had almost entirely divested itself from electronic warfare. The Air Force maintained a small number of electronic warfare officer's (EWOs) even after its move from airborne electronic attack in lieu of stealth technology. The Marine Corps maintained a small number of electronic warfare officers in the form of both EA-6B aircrew and Radio Battalion personnel. Ultimately, the Navy deployed several hundred of its EWOs, both EA-6B aircrew and surface warfare EWOs to Army divisions, brigades, regiments, and battalions in both Iraq and Afghanistan. However, the use of manpower to replace broken processes is not a long-term solution.

RECOMMENDATIONS

As force transformation continues and the military relies more heavily on network-centric operations, unfettered access to the electromagnetic spectrum is becoming a critical requirement in generating and applying combat power. The inefficacy of the legacy construct of spectrum management by frequency allotment will not sustain our need for spectrum access while also balancing the needs of the civilian population. The NTIA and FCC must coordinate to create a unified national strategy for spectrum management within a new construct for increased efficiency in the use of the spectrum. This is a huge departure from the norms established over the last century of human use of the spectrum and will require long term investment and international participation through the UN International

Telecommunications Union, but is the only way to increase use of the overcrowded spectrum.

While expanding requirements for the use of the spectrum hold future consequences to combat power projection, current lack of coordination of the employment of electronic warfare immediately affects mission execution. Legacy coordination tools, such as the JRFL, are no longer capable of ensuring deconfliction between users of the spectrum and execution of electronic warfare. A flexible, dynamic spectrum control mechanism is needed that would function similar to the Airspace Control Order (ACO) published by the Joint Forces Air Component Commander. The mechanism would prioritize frequency requirements and assign frequencies for use during specified periods of time for specified tasks. The scope of such a system is enormous considering the shear numbers of devices and the diversity of the uses of the spectrum.

Recently, the Air Land Sea Application (ALSA) Center addressed "the lack of effective EM spectrum management, coordination, and TTP [tactics, techniques, and procedures] for joint EW" by including it in its next release of the Multi-Service Procedures for the joint Application of Firepower (JFIRE).[32] This document will represent a shift in doctrine, treating electronic warfare as the application of a non-lethal fire that requires coordination in the achievement of an effect. This change in philosophy should be carried further and applied to Joint Publication 3-13.1, Joint Electronic Warfare and Joint Publication 3-09, Joint Fire Support.

Several calls have been made over the last decade for a joint EW office that could coordinate EW doctrine and ensure joint EW training including Congressman Joseph R. Pitts[33] and Captain Robert Field, Commander of U.S. Pacific Fleet's Electronic Attack

Wing.[34] Some as early as 1981 have gone so fare as argue for an Under-Secretary of Defense for Electronic Warfare "to insure coordination of electronic warfare with science and technology and to coordinate readiness, combat and training development, electronic intelligence, and related matters among the services and within the Department of Defense."[35] Indeed such a coordinating center has existed since 1980 when the Joint Electronic Warfare Center (JEWC) was established. Since its establishment, this small organization has undergone constant shift in responsibility, focus, and organization. The JEWC needs to be expanded and empowered to address the enormous tasks of transforming EW processes.

CONCLUSION

The processes and structures that were created to allow effective use of the electromagnetic spectrum over the last century will no longer sustain U.S. military demands. Our reliance on the spectrum requires coordinated, efficient utilization for the continued generation and application of combat power in 21st century.

NOTES

[1] Major David M. Rodriguez, "The Influence of Electronic Warfare on Operational Maneuver." (Monograph, School of Advanced Military Studies, United States Army Command and General Staff College, Fort Leavenworth, Kansas, 15 May 1989).
[2] Assistant Secretary of Defense (Networks and Information Integration), *Department of Defense Net-Centric Spectrum Management Strategy*, (Washington, DC: Department of Defense, June 1993 August 2006), 3.
[3] John Luddy, "The Challenge and Promise of Network-Centric Warfare," (Lexington Institute, February 2005), http://www.lexingtoninstitute.org/docs/521.pdf (accessed 11 April 2008).
[4] Noah Shachtman, "How Technology Almost Lost the War: In Iraq, the Critical networks Are Social – Not Electronic," Wired 15, no. 12 (December 2007), http://www.wired.com/politics/security/magazine/15-12/ff_futurewar (accessed 11 April 2008).
[5] Ellen P. Goodman, "Spectrum Rights in the Telecsom to Come," *San Diego Law Review 41*, no 1 (Winter 2004): 4-5.
[6] Ibid., 5.
[7] Ibid., 5.
[8] Ibid., 5.
[9] *The Communications Act of 1934*, Pub. L. No. 73-416, 48 Stat. 1064 (codified as amended at 47 U.S.C. 151-615b (2000)), quoted in Ellen P. Goodman, "Spectrum Rights in the Telecsom to Come," *San Diego Law Review 41*, no 1 (Winter 2004): 6.
[10] Defense Science Board Task Force on DoD Frequency Spectrum Issues, *Coping with Change: Managing RF Spectrum to Meet DoD Needs*, U.S. Government Report (Washington, DC: Office of the Under Secretary of Defense for Acquisition and Technology, November 2000).
[11] National Telecommunications and Information Administration, "Basic Elements of Spectrum Management: How the Spectrum is Shared," http://www.ntia.doc.gov/osmhome/roosa5.html (accessed 10 April 2008).
[12] Defense Science Board Task Force on DoD Frequency Spectrum Issues, *Coping with Change: Managing RF Spectrum to Meet DoD Needs*, U.S. Government Report (Washington, DC: Office of the Under Secretary of Defense for Acquisition and Technology, November 2000).
[13] National Telecommunications and Information Administration, "NTIA Myths vs. Reality," http://www.ntia.doc.gov/ntiahome/myths.html (accessed 4 April 2008).
[14] Defense Science Board Task Force on DoD Frequency Spectrum Issues, *Coping with Change: Managing RF Spectrum to Meet DoD Needs*, U.S. Government Report (Washington, DC: Office of the Under Secretary of Defense for Acquisition and Technology, November 2000).
[15] U.S. Department of Commerce, Assistant Secretary for Communications and Information "Federal Strategic Spectrum Plan," (March 2008), 8.
[16] U.S. Federal Communication Commission, "Federal Communication Commission

Strategic Plan 2006-2011", http://www.fcc.gov/omd/strategicplan/ (accessed 11 April 2008).
[17] Ibid, 12.
[18] U.S. Department of Commerce, Assistant Secretary for Communications and Information "Federal Strategic Spectrum Plan," (March 2008), B-19.
[19] U.S. Department of Commerce, Assistant Secretary for Communications and Information "Federal Strategic Spectrum Plan," (March 2008), B-20.
[20] U.S. Department of Commerce, Assistant Secretary for Communications and Information "Federal Strategic Spectrum Plan," (March 2008), B-20.
[21] John A. Stine and David L. Portigal, *Spectrum 101: An Introduction to Spectrum Management*, Mitre Technical Report no. 04W0000048 for Office of the Assistant Secretary of Defense-Networks and Information Integration, Spectrum Policy Directorate (Mitre Corporation: Washington C3 Center McLean, Virginia, March 2004), 7-1 – 7-19.
[22] Ibid., 7-20 – 7-23
[23] General Accounting Office, Spectrum Management: Better Knowledge Needed to Take Advantage of Technologies That May Improve Spectrum Efficiency (Washington, DC: General Accounting Office, May 2004), 3.
[24] Gerald R. Faulhaber, "The Question of Spectrum: Technology, Management, and Regime Change" (research paper, Professor, Business and Public Policy, Wharton School, University of Pennsylvania, PA, 2005), http://assets.wharton.upenn.edu/~faulhabe/research.html (accessed 15 April 2008).
[25] Kermit Quick, "A Strategy for International EW," *Journal of Electronic Defense 31,* no. 2 (February 2008): 6.
[26] Chairman, U.S. Joint Chiefs of Staff, *Electronic Warfare*, Joint Publication (JP) 3-13.1 (Washington, DC: CJCS, 25 January 2007), I-3 – I-4.
[27] Alfred Price, *The History of U.S. Electronic Warfare, Volume III, Rolling Thunder trhough Allied Force* (Alexandria, VA: the Association of Old Crows, 2000): 432, quoted in Arthur F. Huber, Gary Carlberg, Prince Gilliard, and L. David Marquet, "Deconflicting Electronic Warfare in Joint Operations," *Joint Forces Quarterly 45*, no. 2 (2007), 89.
[28] Ibid., B-2.
[29] Maryann Lawlor, "Organization Targets Bandwidth Battles," *SIGNAL Magazine*, April 2007.
[30] General William L. Nyland, "Statement, Before the House Armed Services Committee on Marine Corps Vehicle Armoring and Improvised Explosive Device Countermeasures, 21 June 2005, http://armedservices.house.gov/comdocs/schedules/ACMCTestimonyJune21FINAL.pdf (accessed 20 April 2008).
[31] Geoff Fein, "Abundance of Devices In Iraq Causing 'Electronic Fratricide' General Says," *C4I News*, 10 November 2005, 1.
[32] K. DeWalt Alderman and Thomas Brumfield, "Electronic Warfare Coming to JFIRE," *The Air land Sea Bulletin* 2007-2, (May 2007), http://www.alsa.mil/documents/alsb/ALSB%202007-2.pdf (accessed 22 April 2008).
[33] Joseph R. Pitts, Congressman U.S. House of Representatives (statement, Lexington Institute Forum on Electronic Warfare, 5 October 2001), http://www.house.gov/pitts/initiatives/ew/Library/Press/011005s-pitts.htm (accessed 18 April 2008).

[34] "U.S. 'needs to do better' with EW assets," *Jane's Defense Weekly*, 02 November 2005.
[35] Don E. Gordon, *Electronic Warfare: Element of Strategy and Multiplier of Combat Power*(New York: Pergamon Press, 1981), 73.

Bibliography

Alderman, K. DeWalt and Thomas Brumfield. “Electronic Warfare Coming to JFIRE.” *The Air land Sea Bulletin* 2007-2 (May 2007). http://www.alsa.mil/documents/alsb/ALSB%202007-2.pdf (accessed 22 April 2008).

Assistant Secretary of Defense (Networks and Information Integration). *Department of Defense Net-Centric Spectrum Management Strategy.* Washington, DC: Department of Defense, June 1993 August 2006.

Communications Act of 1934, Pub. L. No. 73-416, 48 Stat. 1064 (codified as amended at 47 U.S.C. 151-615b (2000)). Quoted in Ellen P. Goodman, “Spectrum Rights in the Telecsom to Come,” *San Diego Law Review 41,* no 1 (Winter 2004).

Defense Science Board Task Force on DoD Frequency Spectrum Issues. *Coping with Change: Managing RF Spectrum to Meet DoD Needs.* U.S. Government Report. Washington, DC: Office of the Under Secretary of Defense for Acquisition and Technology, November 2000.

Faulhaber, Gerald R. “The Question of Spectrum: Technology, Management, and Regime Change.” Research paper, Professor, Business and Public Policy, Wharton School, University of Pennsylvania, PA, 2005. http://assets.wharton.upenn.edu/~faulhabe/research.html (accessed 15 April 2008).

Fein, Geoff. “Abundance of Devices In Iraq Causing ‘Electronic Fratricide’ General Says.” *C4I News,* 10 November 2005.

Gordon, Don E. *Electronic Warfare: Element of Strategy and Multiplier of Combat Power.* New York: Pergamon Press, 1981.

Lawlor, Maryann. “Organization Targets Bandwidth Battles.” *SIGNAL Magazine,* April 2007.

Luddy, John. “The Challenge and Promise of Network-Centric Warfare.” Lexington Institute, February 2005. http://www.lexingtoninstitute.org/docs/521.pdf (accessed 11 April 2008).

National Telecommunications and Information Administration. “Basic Elements of Spectrum Management: How the Spectrum is Shared.” http://www.ntia.doc.gov/osmhome/roosa5.html (accessed 10 April 2008).

National Telecommunications and Information Administration. “NITA Myths vs. Reality.” http://www.ntia.doc.gov/ntiahome/myths.html (accessed 4 April 2008).

Nyland, General William L., Assistant Commandant of the U.S. Marine Corps. Statement before the House Armed Services Committee on Marine Corps Vehicle Armoring and Improvised Explosive Device Countermeasures, 21 June 2005. http://armedservices.house.gov/comdocs/schedules/ACMCTestimonyJune21FINAL.pdf (accessed 20 April 2008).

Pitts, Joseph R. Congressman U.S. House of Representatives. statement, Lexington Institute Forum on Electronic Warfare, 5 October 2001. http://www.house.gov/pitts/initiatives/ew/Library/Press/011005s-pitts.htm (accessed 18 April 2008).

Price, Alfred. *The History of U.S. Electronic Warfare, Volume III, Rolling Thunder through Allied Force* (Alexandria, VA: the Association of Old Crows, 2000). Quoted in Arthur F. Huber, Gary Carlberg, Prince Gilliard, and L. David Marquet.

"Deconflicting Electronic Warfare in Joint Operations." *Joint Forces Quarterly 45*, no. 2 (2007).

Quick, Kermit. "A Strategy for International EW." *Journal of Electronic Defense 31,* no. 2 (February 2008): 6.

Rodriguez, David M., "The Influence of Electronic Warfare on Operational Maneuver." Monograph, School of Advanced Military Studies, United States Army Command and General Staff College, Fort Leavenworth, Kansas, 15 May 1989.

Shachtman, Noah. "How Technology Almost Lost the War: In Iraq, the Critical Networks Are Social – Not Electronic." Wired 15, no. 12 (December 2007). http://www.wired.com/politics/security/magazine/15-12/ff_futurewar (accessed 11 April 2008).

Stine, John A. and David L. Portigal. *Spectrum 101: An Introduction to Spectrum Management.* Mitre Technical Report no. 04W0000048 for Office of the Assistant Secretary of Defense-Networks and Information Integration, Spectrum Policy Directorate. Mitre Corporation: Washington C3 Center McLean, Virginia, March 2004.

U.S. Department of Commerce, Assistant Secretary for Communications and Information. "Federal Strategic Spectrum Plan," (March 2008).

U.S. Federal Communication Commission. "Federal Communication Commission Strategic Plan 2006-2011." http://www.fcc.gov/omd/strategicplan/ (accessed 11 April 2008).

U.S. General Accounting Office, Spectrum Management. Better Knowledge Needed to Take Advantage of Technologies That May Improve Spectrum Efficiency. Washington, DC: General Accounting Office, May 2004.

U.S. Office of the Chairman of the Joint Chiefs of Staff. *Electronic Warfare.* Joint Publication (JP) 3-13.1. Washington, DC: CJCS, 25 January 2007.